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Acid Attack on Concrete Containing Industrial Wastes

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ABSTRACT

In this paper, the acid attack test is conducted on M30 grade concrete with industrial wastes. Here in this study, GGBS and metakaolin are partially replaced for cement and copper slag is replaced for sand. The simultaneous replacement of these materials is done in each mix. Totally five mixes were prepared including controlmix. GGBS and metakaolin replacement vary from 5% to10% in successive mixes. Similarly the copper slag replacement ranges from 20 to 40%. Two types of acids such as Sulphuric Acid, Hydro chloric Acid with 1%concentration are used at 28 days immersion. From the results, it is observed that the percentage loss of weight is least for the mix containing 5% GGBS, 5% Metakaolin and 20% copper slag. And also for the same mix, the compressive strength of 28 dayssulphuric acid curing is11.07% higher than the concrete with 28 days water curing. Similarly in hydro chloric acid immersion, the compressive strength of concrete is 2.24% higher than the concrete with 28 days water curing. The reason for the acid resistance of concrete is the combined effect of GGBS, Metakaolin and copper slag.

Keywords

CopperSlag, GGBS, Metakaolin, Concrete,Acid Attack.Sulphuric Acid, Hydro Chloric Acid

1.INTRODUCTION

Generally the concrete exposed to acid environment has deterioration due to acid attack. In this present study, the concrete making materials are partially replaced with some industrial by products which have some beneficial effects on concrete in acid environment. Many researches have been done using individual replacement ofthese materials. Here in this study, the simultaneous replacement of GGBS, Metakaolin and copper slag have been used for successive mixes. The combination and proportion of three mineral admixtures are partially replaced in each mix.The following observations are obtained from the literatures done in previous study. The depth of deterioration of metakaolin concrete is smaller than controlconcrete at 90 days H_2SO_4 curing. The weight loss of metakaolin concrete is 45%,35% and 25% than control mix at 30,60 and 90 days respectively. The concrete with the combination of 20% silica fume and 15% metakaolinhas the best resistance to sulphuric acid environment [1]. The addition of metakaolin in concrete gives the better acid resistance. It is observed from that the residual compressive strength of 10% metakaolin concrete at acid environment is higher than control concrete. This is attributed to more and more formation of ettringite[2]. The maximum compressive strength is obtained for the optimum content of 15% metakaolin after acid immersion at 28 days [3]. The best acid resistance is achieved for the concrete mix with 40% GGBS due to its pozzolanic action which modifies micro structure. This will result to fill voids and produce low heat of hydration which improves durability of concrete. The acid resistance of GGBS concrete is 10% more than the control concrete. Likewise the later age acid resistance property is also improved by GGBS concrete[4].The weight loss of concrete with 40, 50, 60% GGBS is o.25%, 0.22% and 0.21% lower than control mix respectively [5]. Similar results were obtained for 40% GGBS concrete has the best acid resistance character [6]. The addition of mineral admixtures in concrete produces more acid resistance concrete [7]. The concrete containing 40% GGBS has better resistance in both H_2SO_4 and HCl acid environment. Similarly the compressive strength of concrete is also increased in GGBS concrete in H_2SO_4 and HCl acid environment[8]. The expansion of pozzolan concrete is 65.21% reduced thancontrol concrete due to its pozzolanic activity. The pozzolanic materialdensifies the micro structure by the pozzolanic action which reduces the porosity of concrete [9]. The weight loss of concrete exposed to acid environment is decreased by the pozzolanic materials [10]. About 1.5% mass gain is obtained by the concrete with high proportion copper slag due to continued hydration of cement, formation of gypsum and increase absorbed water in mix. This will lead to increase in crushing load of concrete [11]. the weight of samples are increased 46.8%, 49.2%, 58.2%, 62.4%, 64.2%, 67.7% than controlmix for 10%, 20% 30%, 40%, 50% and 60% of copper slag replacement respectively [12]. The copper slag concrete has better acid resistance than controlconcrete[13,14,15].

The objectives of this study are (i) To improve the acid resistance of concrete with the simultaneous replacement of GGBS, Metakaolin and Copper slag in each mix. (ii) To utilize the industrial by products effectively by replacing theconventional concrete making materials. (iii) To enhance the performance of concrete exposed to acid environment by the partial replacement of mineral admixtures such as GGBS, Metakaolin, copper slag.

2.MATERIALS AND MIX DESIGN

Ordinary Portland cement 43 grade having fineness modulus 2 and specific gravity 3.15 confirming to IS12269-1987 was used [17]. GGBS is obtained from Nandi cements, Bangalore which is extracted from steel or iron manufacturing industry as a by-product. Metakaolin is obtained from Astraa Chemicals, Chennai which is the calcination of kaolinitic clay at a temperature ranging between 500°C and 800°C. Fine aggregate of river sand confirming to IS383-1978 was used [18]. Copper slag was obtained from Sterilite industry, Tuticorin. Coarse aggregate of crushed rock gravel confirming to IS383-1978 was used [18]. In this study, ordinary potable water is used which reacts and forms the hydration properties of concrete. Super-plasticizer (CONPLAST 420) has high range water reducing admixture was used. Mix design for M30 grade concrete was obtained having mix proportion of 1: 1.21: 2.77 and water/binder ratio of 0.38 and super-plasticizer 0.75% as per IS10262: 2009 [16].The mix quantity and mix proportions are shown in Table no.1 and 2 respectively.Three specimens are cast for each mix and the average value is taken as the result.

Table1. Concrete mix Quantity

Material	Quantity in Unit
Cement	391.58 kg/m^3
Sand	638.56 kg/m^3
Coarse aggregate	1245.65kg/m^3
Water	148.8 kg/m^3
Super plasticizer	2.94 kg/m^3
Water-cement ratio	0.38

Table 2. Mix Proportions

MIX ID	BINDER			FINE AGGREGATE	
	CEMENT	GGBS	METAKAOLIN	SAND	COPPER SLAG
	%	%	%	%	%
C MC1	100	0	0	100	0
MC2	90	5	5	80	20
MC3	80	10	10	80	20
MC4	90	5	5	60	40
MC5	80	10	10	60	40

3.TESTING PROCEDURE

3.1Sulphuric Acid attack Test

The acid resistance was carried out on 100mm size cube specimen at the age of 28 days curing. The cube specimen were weighted and immersed in water diluted with one percent by weight of sulphuric acid for 28 days. Then the specimens were taken out from the acid and the surfaces of the cubes were cleaned. Then the weight and the compressive strength of the specimens were found out the average percentage of loss of weight and compressive strengths were calculated.

% loss of weight $=\frac{W2-W1}{W1}$ X 100

Where,

W1 - Weight of specimen after 28 days of water curing.

W2 - Weight of specimen after 28 days of sulphuric acid curing.

3.2Hydrochloric Acid attack Test

The acid resistance was carried out on 100mm size cube specimen at the age of 28days curing. The cube specimen were weighted and immersed in water diluted with one percent by weight of hydrochloric acid for 28 days. Then the specimens were taken out from the acid and the surfaces of the cubes were cleaned. Then the weight and thecompressive strength of the specimens were found out the average percentage of loss ofweight and compressive strengths were calculated.

% loss of weight $=\frac{W2-W1}{W1}$ X 100

Where,

W1 - Weight of specimen after 28 days of water curing.

W2 - Weight of specimen after 28 days of hydrochloric acid curing.

4.RESULTS AND DISCUSSIONS

Table 3. Acid Attack Results

MIX ID	Sulphuric acid Attack			Hydro Chloric Acid Attack		
	Percentage loss in weight	Normal strength N/mm^2	Strength(28 days) N/mm^2	Percentage loss in weight	Normal strength N/mm^2	Strength (28 days) N/mm^2
C MC1	0.525	38.51	37.82	0.734	38.51	36.25
MC2	0.393	30.81	34.22	0.590	30.81	31.50
MC3	0.505	40.21	38.01	0.625	40.21	39.10
MC4	0.550	47.88	45.8	0.741	47.88	44.32
MC5	0.680	54.78	50.62	0.808	54.78	52.62

4.1 Mass loss in concreteexposed to acid environment

Table no 3 shows the percentage loss in weight of concrete exposed to acid environment. The weight loss of specimen immersedinsulphuric acid after 28 days is decreased up to 20% copper slag replacement. Beyond that limit, the weight loss of specimen is increased. The maximum weight loss is obtained for the mix containing 10% GGBS, 10% Metakaolin and 40% copper slag replacement. The maximum weight gain is achieved for the mix containing 5% GGBS, 5% Metakaolin and 20% copper slag replacement. For the mix containing 20% copper slag replacement has the lower mass loss than control concrete. But the least mass lossis achieved for the mix containing 5% GGBS, 5% metakaolin and 20% copper slag. However the mass loss is higher for the mix containing 40% copper slag. The pozzolanic action of GGBS and metakaolin produces more dense concrete. This will result to fill the pores of concrete. This is attributed to resist the acid entry into the concrete. Similar behavior is obtained for hydro chloric acid immersion.

4.2StrengthReduction in concreteexposed to acid environment

Table no 3 shows the compressive strength of concrete exposed to acid environment. Similarly the compressive strength of concrete containing 5% GGBS, 5% Metakaolin and 20% copper slag at 28 days sulphuric acid curing has 11.07% higher than the concrete with 28 days water curing. The other mixes have the lower compressive strength at 28 days sulphuric acid curing than 28 days water curing concrete. Similar behavior is obtained for the specimen exposed to hydro chloric acid. The compressive strength of concrete containing 5% GGBS, 5% Metakaolin and 20% copper slag at 28 days sulphuric acid curing has 2.24% higher than the concrete with 28 days water curing.The reason for improving acid resistance is the pozzolanic action of GGBS and metakaolin which produce densified micro structure. Another reason is due to continued cement hydration and an early formation of gypsum and ettringite which fill the pores of concrete. By this activity, the deterioration of the concrete is prevented. The combination of three admixtures improves the resistance of concrete by their beneficial effects on concrete.

5.CONCLUSION

The following conclusions are made from the experimental results.

- The effect of using optimum contents of GGBS, Copper slag and metakaolin, as partial replacement of concrete has better resistance to acid than control concrete.
- The mass loss is reduced for the specimen immersed in sulphuric acid and hydro chloric acid after 28 days than control specimen due to the simultaneous replacement of GGBS, Metakaolin and copper slag.
- Likewise the compressive strength of concrete with GGBS, Metakaolin and copper slag after 28 days immersion in sulphuric acid and hydro chloric acid is 11.07% and 2.24% greater than concrete with 28 days waterimmersion respectively.
- It was found that there is a beneficial effect of incorporating combination of three admixtures 5% GGBS, 5%metakaolin and 20% copper slag on concrete sulphuric acid and hydro chloric resistance.
- It was achieved a reduction in mass loss than that for control mix, after immersion 28 days in 1% sulphuric acid and also for 1% hydro chloric acid.

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